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The quality of the assignment matters in hypermedia learning

Cindy Paans[1] | Eliane Segers[1,2] | Inge Molenaar[1] | Ludo Verhoeven[1]

[1] Behavioural Science Institute, Radboud University, Nijmegen, The Netherlands

[2] Instructional Science, University of Twente, Enschede, The Netherlands

Correspondence
Cindy Paans, Behavioural Science Institute, Radboud University, Montessorilaan 3, 6525 HR Nijmegen, The Netherlands.
Email: c.paans@psych.ru.nl.

Abstract

In the present study, we investigated whether online learning behaviours (navigation and writing activities) mediated the relation between learner characteristics (prior knowledge, vocabulary knowledge, working memory, and motivation) and declarative knowledge. Specifically, we investigated whether the quality of participants' written assignments could further explain this relation. For this purpose, 62 fifth-grade children participated in a WebQuest hypermedia assignment on the subject of the heart. Results showed that online learning behaviours did not mediate the relations between learner characteristics and declarative knowledge when the assignment quality was not included in the model. Adding assignment quality, however, revealed two serial mediation models. Prior knowledge predicted declarative knowledge via the writing activity "copying behaviour" and assignment quality, and vocabulary knowledge predicted declarative knowledge via the navigation activity "time spent on assignment pages" and assignment quality. These results show the importance of taking into account assignment quality when investigating knowledge acquisition in hypermedia environments.

KEYWORDS

hypermedia, navigation activities, online learning behaviour, primary education, self-regulated learning

1 | INTRODUCTION

In today's society, the Internet is pervasive. For children, it is therefore important to become digitally literate and to learn how to gain declarative knowledge (i.e., knowledge of facts) in hypermedia environments, such as the Internet, that combine hypertext with pictures and movies. To achieve these goals, primary education often stimulates children to gain declarative knowledge on the Internet by means of assignments, such as writing a paper or an essay. However, research often does not take into account the learning context when investigating knowledge acquisition on the Internet. What further complicates the matter is that hypermedia faces some serious challenges, one of which is that the hypertext structure creates high cognitive load (DeStefano & LeFevre, 2007). Three learner characteristics that help to reduce cognitive load are having higher prior knowledge (both domain specific and general), larger working memory capacity, and higher motivation (Verhoeven, Schnotz, & Paas, 2009). However, much is still unknown regarding the mechanisms by which learner characteristics influence declarative knowledge gains. In investigating these mechanisms, research has increasingly focused on online measurement during learning. For example, students' navigation activities, which provide information on how learners move through the hypermedia environment during learning, are a proposed online measure of students' learning behaviour (Hadwin, Nesbit, Jamieson-Noel, Code, & Winne, 2007).

On top of that, online learning behaviours also include the students' writing activities. Finally, taking into account the quality of their final work could increase our understanding of how declarative knowledge is gained. In the present study, we therefore investigated how children's learner characteristics (prior knowledge, vocabulary knowledge, working memory, and motivation) predicted their declarative knowledge outcomes via online learning behaviour (navigation activities and writing activities) and the quality of the assignment.

1.1 | Individual variation in hypermedia learning outcomes

Children differ in the extent to which they are able to gain declarative knowledge in hypermedia settings. Cognitive load theory helps to explain this individual variation (DeStefano & LeFevre, 2007). It considers the following learner characteristics to be crucial: information stored in long-term memory, for example, in the form of domain specific knowledge (prior knowledge) and general knowledge (e.g., vocabulary knowledge), and working memory capacity (Kalyuga, 2009). To a lesser extent, it also emphasizes the importance of motivation (Verhoeven et al., 2009). Together, and in interaction with, characteristics of the learning context, these learner characteristics explain how much cognitive load a learner experiences during learning (Kalyuga, Ayres, Chandler, & Sweller, 2003; Mayer & Moreno, 2003; van Merriënboer & Sweller, 2005). Empirical evidence supports the importance of these learner characteristics for gaining declarative knowledge in hypermedia environments. First, prior knowledge and vocabulary knowledge are important in hypermedia learning (e.g., Boechler, Levner, Leenaars, & Steffler, 2006; Ford & Chen, 2000). They are both pivotal to reading comprehension, in linear text as well as in hypertext (Chen, Fan, & MacRedie, 2006; Fesel, Segers, & Verhoeven, 2017; Moos & Marroquin, 2010; Salmerón & García, 2011; Salmerón, Kintsch, & Kintsch, 2010). In a similar vein, working memory affects learning outcomes on the Internet (Pazzaglia, Toso, & Cacciamani, 2007). Working memory is the ability to keep information in mind and at the same time mentally manipulate it (Diamond, 2013). It has also been related to academic achievement in general (e.g., Alloway & Alloway, 2010; Best, Miller, & Naglieri, 2011; Diamond, Barnett, Thomas, & Munro, 2007). Finally, motivation is an important factor in hypermedia learning (Kuiper, Volman, & Terwel, 2005; Moos & Marroquin, 2010; Verhoeven et al., 2009; Wang, Shannon, & Ross, 2013). Motivation can be defined as the way in which a person's beliefs, values, and goals relate to their achievement behaviours (Eccles & Wigfield, 2002). It helps learners to invest time and effort in the learning process (Pintrich, 1999).

1.2 | Variation in hypermedia learning behaviour

Cognitive load theory describes the cognitive mechanism by which individual differences predict learning outcomes. However, it does not describe how learners regulate their own cognitive activities or their learning context. A research field that does investigate this is self-regulated learning (SRL). SRL is the self-directed process by which the thoughts, feelings, and behaviours of an individual are directed at reaching a learning goal (Zimmerman, 2000). Being a successful self-regulating learner requires the use of cognitive, metacognitive, and motivational activities during learning (Veenman, 2011; Winne & Nesbit, 2010; Zimmerman, 2001, 2011).

In order to understand the mechanisms by which cognitive, metacognitive, and motivational activities predict declarative knowledge in hypermedia environments, research benefits from a focus on children's online learning behaviour (Hadwin et al., 2007; Jamieson-Noel & Winne, 2003; Winne, 2010). Log files that capture children's navigation activities (i.e., the activities that characterize how children navigate through the hypermedia environment) and other online learning behaviours, such as highlighting and note-taking, have been advocated as a possible way to measure SRL activities (Jamieson-Noel & Winne, 2003; Winne, 2010). However, making the step from these log file measures to SRL is often considered difficult (Azevedo, Moos, Johnson, & Chauncey, 2010). Therefore, it may be worthwhile to first explore what relationship can be found between children's navigation activities on the one hand and their learner characteristics and declarative learning outcomes on the other, without making direct inferences to SRL.

In previous research, navigation activities have been linked to learning outcomes. For example, differences in navigation profiles were shown to impact the complexity of concept maps drawn by high school students (MacGregor, 1999). Similarly, Salmerón and García (2011) found that both a cohesive reading order and looking at an overview of the webpage at the start of a learning session were positively related to learning. Navigation activities have also been linked to learner characteristics. First, prior knowledge has been associated with differences in navigation patterns (Ford & Chen, 2000; MacGregor, 1999). Students with high prior knowledge used more navigation strategies that were useful for later recall. Low prior knowledge students had more difficulty doing so, showed more random clicking, and were more occupied with special features of the hypermedia environment (Lawless, Brown, Mills, & Mayall, 2003). Second, reading skills have been related to the use of link selection strategies in sixth graders (Salmerón & García, 2011). Reading comprehension was found to be related to reading performance during a Web assignment in high school children, but only for those who selected relevant pages (Naumann & Salmerón, 2016). Third, although working memory capacity has not directly been related to navigation activities, a related learner characteristic called sustained attention has. Sustained attention is the ability to focus on a single object over a longer period. For instance, 11-year-olds with low sustained attention abilities benefited more from hypertext with a navigation overview than from printed text (Salmerón & García, 2012). Sustained attention was also related to link selection strategies, web reading strategies, and the frequency of unsuccessful navigation actions in undergraduate students (Desjarlais, 2013). Last, motivation has been linked to hypermedia navigation in that task interest and self-efficacy were important in predicting navigation activities (Moos & Marroquin, 2010).

To conclude, research has shown the importance of investigating online learning behaviours in order to increase understanding of how learner characteristics affect declarative knowledge outcomes in hypermedia learning. Indeed, previous research has linked navigation activities to learning outcomes, as well as to relevant learner characteristics. However, to our knowledge, no research has measured all these three factors (learner characteristics, online learning behaviour, and learning outcomes) concurrently. Therefore, although it is likely that

individual differences in learner characteristics affect learning outcomes via navigation activities, evidence for this hypothesis is limited.

1.3 | Quality of the assignment as additional factor in explaining declarative knowledge

Online learning behaviour is complex and can take many forms. Navigation activities are not the only way to describe the children's learning processes. When children learn in an Internet environment, their gain in declarative knowledge is often achieved by doing an assignment, such as preparing a presentation, or writing an essay. This is important, because task characteristics are known to affect learning behaviours and learning outcomes (e.g., Segers & Verhoeven, 2009). Doing an assignment can be broken down into two components: writing activities (e.g., how much text learners write and how much text they copy from the website) and the quality of the final work (e.g., the essay). Writing activities are online learning behaviours, such as navigation activities. Differences in writing activities have been related to other online learning behaviours and learning outcomes. For example, the number of words that are written as well as the amount of original (not-copied) text are important in understanding cognitive learning activities (Molenaar & Chiu, 2017). Additionally, copy-paste behaviour has been associated with lower knowledge retention as well as with making longer notes (Bauer & Koedinger, 2006). The quality of the final work is often considered a learning outcome, like declarative knowledge. However, sequentially, the quality of the final work precedes declarative knowledge in time because the final work is being prepared throughout the learning activity. Declarative knowledge, on the other hand, is usually only measured afterwards, to establish what knowledge has been retained in long-term memory. As such, the quality of the assignment may be affected by online learning behaviours, such as navigation and writing activities, but may also predict declarative knowledge outcomes. Therefore, a serial mediation model from learner characteristics to declarative knowledge via online learning behaviour and assignment quality might explain additional variation in declarative knowledge outcomes in hypermedia learning. The extent to which this is the case has not been previously investigated.

1.4 | The present study

To conclude, the current study adds to the existing literature in two important ways. First, it is one of the few studies that measures learner characteristics, online learning behaviour, and learning outcomes concurrently. Second, it is the first to investigate how assignment quality mediates the relations between learner characteristics and declarative knowledge. We investigated whether a serial mediation model, from learner characteristics to declarative knowledge, via online learning behaviour and assignment quality could explain variation in declarative learning outcomes (see Figure 1). The relevance of this study lies in the fact that results may help both teachers and researchers to understand the complex interactions between learner characteristics, process measures, and outcome measures. Especially taking into account the quality of the assignment is of relevance for teacher awareness of the impact of including such methods in the curriculum.

For this purpose, we investigated two research questions. The first question was: Do online learning behaviours (navigation activities and writing activities) mediate the relations between learner characteristics (prior knowledge, vocabulary knowledge, working memory, and motivation) and declarative knowledge after learning? We expected that these learner characteristics would predict declarative knowledge. In addition, we expected that these relations would be mediated by online learning behaviour. In our second question, we investigated to what extent assignment quality was a useful addition to this mediation model. Therefore, the second research question was: To what extent can online learning behaviours mediate the relations between learner characteristics and declarative knowledge via assignment quality? In order to investigate this research question, we first tested the extent to which learner characteristics predicted assignment quality, and whether online learning behaviours mediated this relationship. Next, we investigated whether learner characteristics predicted declarative knowledge, via online learning behaviour and assignment quality. We expected that a serial mediation model that included assignment quality would explain more variance in declarative knowledge than a model without assignment quality.

2 | METHOD

2.1 | Participants

Participants were 62 fifth-grade children (24 boys and 38 girls) from three different primary schools in the Netherlands. Schools were recruited via letter and the informal network of the authors. Passive parental consent was obtained by letter. The children's age ranged from 9 to 12 years (*M*: 10 years, 6.5 months; *SD*: 0.59). Ethnicity was very diverse: 46.8% of the participants had two Dutch parents, 12.9% had two Turkish parents, 8.1% had Moroccan parents, and 32.2% were of other or mixed ethnicity. This was more diverse than the general Dutch population (Centraal Bureau voor de Statistiek, 2015). During the analyses, we checked whether this affected our results.

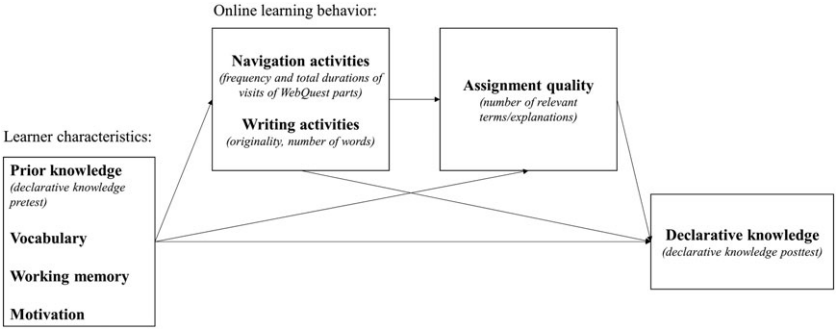

FIGURE 1 Theoretical mediation model for the relation between learner characteristics and declarative knowledge during a writing assignment

2.2 | Materials

2.2.1 | Hypermedia assignment

For the purpose of the study, a WebQuest was designed (see Ikpeze & Boyd, 2007; Segers & Verhoeven, 2009). This is a sheltered Internet environment in which children explore a topic by performing an assignment with the help of a set of preselected hypermedia sources. The assignment was to write a piece of text of approximately 300 words about the heart and living a healthy lifestyle for children in Grade 3. This text had to include information about the components of the heart, the circulatory system, and behaviours that help the heart to stay healthy. Six content pages with text and pictures were provided, as well as four short videos. The content pages contained hyperlinks to each other and hyperlinks relating to the navigational path (e.g., "home" or "go back to content overview"). On the left, the website had a navigation menu, which contained links to the following pages: an introductory page, an assignment page that explained the assignment, a roadmap page that divided the assignment into several steps, a content overview in which the hyperlinks to the six content pages were provided, a review page where children could review their work, and a conclusion page. Children wrote their assignment in a word-processing document.

2.2.2 | Learner characteristics

We measured the following learner characteristics: prior knowledge, vocabulary knowledge, working memory, and motivation. As prior knowledge was measured in the same manner as declarative knowledge, it will be described in the relevant section.

Vocabulary knowledge

Vocabulary knowledge was assessed via the vocabulary part of the Taaltoets Allochtone Kinderen Bovenbouw TAK BB; (Verhoeven & Vermeer,1993). This Dutch test is aimed at both native and immigrant children in the upper primary grades and consists of 50 multiple-choice questions. Each question consists of a sentence with one underlined word that is correctly explained by one of four answer alternatives. The task was untimed, and the score consisted of the number of items correct.

Working memory

Working memory was assessed using the backward digit span task (Wechsler, 2005). In this task, participants repeated sequences of spoken digits back to the test leader in reverse order. The sequences increased by one in length from two digits to eight. The task ended when children could not correctly recall two sequences of the same length. Scores reflected the number of sequences that were correctly recalled.

Motivation

Task motivation was measured prior to the assignment using the Online Motivation Questionnaire (Boekaerts, 2002). This paper and pencil questionnaire assesses five subcomponents in relation to a specific task: emotional state, subjective competence, task attraction, perceived relevance, and learning intentions prior to the learning task. This questionnaire has been extensively validated for use in children of 11 years and older (see Boekaerts, 2002). To make sure the younger participants in our study also sufficiently understood the test, the task was untimed, and someone was available throughout the test administration to provide help, if needed. Because not all subscales were sufficiently reliable, only the total scale was analysed. The maximum total score was 96. Internal consistency was good for the total scale (α = 0.89).

2.2.3 | Online learning behaviour

Navigation activities

Log files were used to assess the navigation activities. Within the website, every link selection was recorded, together with a time stamp to a 1-s precision. Next, frequencies and cumulative durations of page visits for each web page were calculated. Pages were then grouped together to reflect various aspects of the assignment. Specifically, the assignment and roadmap page were grouped together to reflect the assignment part of the website. The review and conclusion page were grouped together to reflect the review part of the website. Content pages were also grouped together. The content overview was not analysed because this page contained the links to the content pages rather than actual content. Summarizing, log file measures were frequencies and total durations of viewing of assignment pages, review pages, and content pages.

Writing activities

Two writing activities were assessed. First, to get insight into participants' copying from the website, an originality score was calculated. For this purpose, the percentage of original text was calculated with the help of the program WinCopyFind. Second, the number of words that were written during the assignment was counted.

2.2.4 | Hypermedia learning

Assignment quality

The quality of the written assignment was assessed by counting the number of relevant terms used and explanations provided, with the help of a predefined list of 50 items. All assignments were scored by two raters, and inter-rater agreement was high (intra-class correlation: 0.98). The total number of relevant terms and explanations that were mentioned in the assignment constituted the final score.

Declarative knowledge test

In order to measure declarative knowledge, a connecting task was made for the purpose of this study.[1] Children had to connect 14 terms from the website (e.g., white blood cell) to sentences that explained those terms (e.g., "helps fight disease"). The same test was administered twice, once before, and once after the Internet assignment. An example item was given during the first administration. The task was not timed, and participants were encouraged to first write down the answers they knew and guess the others. The score was the number of correct items. Internal consistency was acceptable to good on both pretest (α = 0.75) and post-test (α = 0.78). The first administration constituted prior knowledge, whereas the second administration constituted the declarative knowledge outcome.

[1]The task also included a labelling task. This task is not reported in the current study to increase conceptual clarity.

2.3 | Procedure

The current study was part of a larger data collection. Only those aspects relevant to the current study are described below. Data collection in each classroom consisted of three sessions. First, the classroom session took approximately 1 hr and 15 min to complete and included a booklet with demographic information and the prior knowledge measure, a presentation of the website, and the vocabulary knowledge test. Second, the first individual session took 25 min and included the working memory task. Third, the second individual session took 1 hr and 15 min and included another explanation of the website, the motivation questionnaire, the WebQuest assignment, and a booklet with the declarative knowledge post-test. Sessions never directly followed each other to prevent fatigue effects. After participating, children received a small gift.

The procedure concerning the WebQuest was as follows: Only questions regarding the procedure or the computer were answered. When content-related questions arose, children were referred to the website. The assignment took 45 min to complete, and children were reminded three times of the time they had left: after 15, 30, and 40 minutes. When participants indicated that they had finished earlier, they were asked to reread the assignment page and say whether or not they had finished. If they had finished, the WebQuest ended. If not, they could continue working on their assignment. If, however, children already indicated that they had finished before 25 min had elapsed, they were encouraged to keep working by looking through the assignment together. For use in another study, the assignment was video recorded, and children were asked to think aloud. The test leader reminded them to think aloud during the entire assignment and prompted them to "keep expressing what they were thinking" when they fell silent (Ericsson & Simon, 1993).

2.4 | Analyses

In order to investigate the first research question—Do online learning behaviours mediate the relation between learner characteristics and declarative knowledge?—the data were analysed in three steps. First, we used hierarchical regression analyses to investigate whether learner characteristics (prior knowledge, vocabulary, working memory, and motivation) were related to declarative knowledge. In the analyses of vocabulary, working memory, and motivation, prior knowledge was included as a control variable. Second, correlations between learner characteristics, online learning behaviour, and declarative knowledge were assessed. Online learning behaviour measures that correlated with both a learner characteristic and declarative knowledge were selected as potential mediators for the variables with which they correlated. Finally, mediation analyses were performed using the Process procedure of Hayes (Preacher & Hayes, 2004). A resampling strategy of 5,000 bootstraps was used. Models could include multiple mediators, if multiple online learning behaviours showed significant correlations with the same set of independent and dependent variables. In such cases, the mediators were analysed in parallel.

In order to investigate the second research question—To what extent can online learning behaviours mediate the relation between learner characteristics and declarative knowledge via assignment quality?—we first tested the extent to which learner characteristics predicted assignment quality, and whether online learning behaviour mediated this relationship. The procedure followed was similar to that used to investigate the extent to which learner characteristics predicted declarative knowledge via online learning behaviours. The only difference was that relations between learner characteristics and assignment quality were assessed using Pearson correlations, rather than hierarchical regression analyses. Next, we tested serial mediation models. Potential models were selected based on the results found in the previous steps. Only those learner characteristics that showed significant relations with assignment quality as well as declarative knowledge were tested. Similarly, only those online learning behaviours that showed significant indirect paths from a learner characteristic to assignment quality or declarative knowledge were selected.

3 | RESULTS

3.1 | Descriptive statistics

Means and standard deviations of the various measures are displayed in Table 1. In order to establish whether learning took place, a paired samples t test was performed. On average, children showed an increase of 2.13 (SD = 2.69) from pretest to post-test, $t(60) = 6.18$, $p < .001$; Cohen's $d = 0.73$. The WebQuest therefore produced a learning gain. With respect to the relation between the learning outcome measures, the quality of the assignment predicted declarative knowledge over and above prior knowledge, $F_{change}(1, 58) = 6.39$, $p = .014$, $R^2 = .41$, $\Delta R^2 = .07$, $b = .12$.

We checked whether ethnicity, home language, or gender needed to be included as a covariate in the analyses. Comparing Dutch-speaking to non-Dutch-speaking participants, participants with two Dutch

TABLE 1 Descriptive statistics of the learner characteristics, online learning behaviour, and outcome measures

	Min	Max	*M*	*SD*
Prior knowledge	0	10	2.94	2.59
Vocabulary	14	45	32.87	7.24
Working memory	2	7	4.31	1.25
Motivation	38	85	69.75	8.61
Assignment quality	0	37	15.48	7.42
Declarative knowledge	0	14	5.07	3.19
Knowledge gain	−3.00	9.00	2.13	2.69
Frequencies				
Assignment	0	40	7.20	6.92
Content	2	45	17.18	10.28
Review	0	6	1.31	1.66
Total durations				
Assignment	0	865	191.15	153.01
Content	905	2,591	1,870.97	432.09
Review	0	466	55.25	100.92
Originality score	8.19	100.00	82.57	25.96
No. of words	0	1,136	213.30	162.15

Note. Page durations are in seconds, and total time given for WebQuest assignment was 2,700 s.

parents to participants with at least one non-Dutch parent, and boys to girls showed no differences in learning gain or assignment quality (all *p*'s > .10). Therefore, we did not include these factors as covariates, which increased power.

3.2 | Online learning behaviour as mediator between learner characteristics and declarative knowledge

To answer the first research question—Do online learning behaviours mediate the relation between learner characteristics and declarative knowledge?—whether learner characteristics (prior knowledge, vocabulary knowledge, working memory, and motivation) predicted declarative knowledge was first investigated. Correlations between the variables are displayed in Table 2. Prior knowledge predicted declarative knowledge (r = .58, p < .01). In addition, vocabulary knowledge was a positive predictor, $F_{change}(1, 58) = 16.17$, p < .001, R^2 = .49, ΔR^2 = .14, b = .19, over and above prior knowledge. Working memory and motivation did not predict declarative knowledge (p > .10).

In the next step, in order to answer the first research question, we investigated in what way online learning behaviour mediated the relations between learner characteristics and declarative knowledge. Table 3 shows the correlations between online learning behaviour measures on the one hand and the learner characteristics and learning outcomes on the other.

A total of three mediation analyses were performed. Declarative knowledge was predicted by (a) prior knowledge via originality, (b) vocabulary knowledge via the total duration spent on assignment pages, and (c) motivation via the number of words that were written. In the second and third model, we controlled for prior knowledge. Results were as follows. First, prior knowledge predicted declarative knowledge, p < .001; direct effect: b = 0.68 (0.15), p < .001, CI: [0.39; 0.97], but this relation was not mediated by originality, b = 0.013 (0.09), CI: [−0.15; 0.23]. Second, vocabulary predicted declarative knowledge, p < .001; direct effect: b = 0.20 (0.05), p < .001, CI: [0.09; 0.30], but this relation was not mediated by the total duration spent on assignment pages, b = −0.01 (0.02), CI: [−0.07; 0.03]. Finally, motivation did not predict declarative knowledge over and above prior knowledge (p = .270) either directly, b = 0.02 (0.04), p = .576, CI: [−0.06; 0.10], or indirectly via the number of words that were written, b = 0.02 (0.02), CI: [−0.01; 0.05].

To sum up, declarative knowledge was predicted directly by prior knowledge and vocabulary knowledge. These relations were not mediated by online learning behaviours.

TABLE 2 Correlations for learner characteristics and learning outcomes

	1.	2.	3.	4.	5.	6.
Learner characteristics						
1. Prior knowledge						
2. Vocabulary	0.47**					
3. Working memory	0.04	−0.03				
4. Motivation	0.05	0.17	−0.08			
Learning outcomes						
5. Assignment quality	0.24	0.36**	−0.06	0.39**		
6. Declarative knowledge	0.58**	0.61**	−0.05	0.15	0.39**	
7. Knowledge gain	−0.28*	0.27*	−0.10	0.13	0.22	0.62**

*Significant at the 0.05 level. **Significant at the 0.01 level.

3.3 | Online learning behaviour as mediator between learner characteristics and assignment quality

Analyses of our second research question—To what extent can online learning behaviours mediate the relation between learner characteristics and declarative knowledge via assignment quality?—proceeded in two steps. The first step will be described below, and the second step will be described in the next section.

In the first step, we tested whether learner characteristics predicted assignment quality and the extent to which online learning behaviour mediated this relationship. Results showed that vocabulary and motivation positively correlated with assignment quality (see Table 2). Multiple regression showed that vocabulary (b = 0.28, p = .018) and motivation (b = 0.29, p = .006) both predicted the assignment quality, independently of each other (R^2 = .23, p = .001).

Next, three mediation analyses were performed. Assignment quality was predicted by (a) prior knowledge via originality, (b)

TABLE 3 Correlations between online learning behaviour measures, learner characteristics, and learning outcomes

	Prior knowledge	Vocabulary	Working memory	Motivation	Assignment quality	Declarative knowledge
Frequencies						
Assignment	−0.19	−0.27*	−0.15	0.00	−0.26*	−0.09
Content	−0.10	−0.07	−0.14	0.00	−0.23	−0.07
Review	−0.11	−0.05	0.11	−0.19	−0.18	−0.16
Total durations						
Assignment	−0.20	−0.47**	−0.01	−0.17	−0.45**	−0.25*
Content	0.03	0.11	0.10	0.00	0.09	0.01
Review	−0.04	0.13	0.08	0.00	−0.09	0.00
No. of words text	0.10	0.17	−0.03	0.26*	0.74**	0.30*
Originality score	−0.44**	−0.25	−0.12	0.02	−0.54**	−0.27*

*Significant at the 0.05 level. **Significant at the 0.01 level.

vocabulary knowledge via the total duration spent on, and frequency of, assignment page visits, and (c) motivation via the number of words that were written. The results were as follows. First, prior knowledge predicted assignment quality marginally (p = .079), via originality, b = 0.61 (0.30), CI: [0.15; 1.37]. The direct effect was not significant, b = −0.02 (0.32), p = .944, CI: [−0.66; 0.61]. Second, vocabulary knowledge predicted assignment quality (p = .005) via the total duration spent on assignment pages, b = 0.16 (0.09), CI: [0.05; 0.41], but not the frequency of assignment page visits, b = 0.01 (0.05), CI: [−0.04; 0.15]. The direct effect was not significant, b = 0.19 (0.13), p = .162, CI: [−0.08; 0.45]. Finally, motivation predicted the assignment quality (p = .002) both directly, b = 0.18 (0.08), p = .020, CI: [0.03; 0.33], and via number of words, b = 0.15 (0.05), CI: [0.03; 0.23].

To sum up, assignment quality was predicted directly by motivation. In addition, it was predicted indirectly by prior knowledge via originality, by vocabulary knowledge via the total duration spent on assignment pages, and by motivation via the number of words that were written.

3.4 | Serial mediation of learner characteristics and declarative knowledge

In the second step to answer the second research question, we performed two serial mediation analyses. The analyses described in the previous sections showed that assignment quality predicted declarative knowledge. Additionally, prior knowledge predicted declarative knowledge and predicted the assignment quality via originality. Vocabulary knowledge predicted declarative knowledge and predicted the assignment quality via the total duration spent on assignment pages. Motivation on the other hand predicted assignment quality via the number of words, but not declarative knowledge. Therefore, two models were tested. Declarative knowledge was predicted by (a) prior knowledge via originality and assignment quality and (b) vocabulary knowledge, via the total duration spent on assignment pages and assignment quality. In the second model, we controlled for prior knowledge.

The results were as follows. In our first model, prior knowledge predicted declarative knowledge directly, b = 0.69 (0.14), p < .001, CI: [0.41; 0.97]. In addition, prior knowledge predicted declarative knowledge indirectly via the mediators originality and assignment quality, b = 0.09 (0.08), CI: [0.01; 0.34]. Prior knowledge negatively predicted originality which negatively predicted assignment quality which, in turn, positively predicted declarative knowledge. In other words, those children who had greater prior knowledge copied more text from the website and, consequently, had a higher assignment quality and, finally, showed greater declarative knowledge. This serial mediation model predicted 40.1% of variance in declarative knowledge outcomes, whereas a model without assignment quality predicted 33.5% of variance.

In our second model, vocabulary knowledge predicted declarative knowledge directly, b = 0.18 (0.05), p < .001, CI: [0.08; 0.29]. The indirect path via the total duration spent on assignment pages and assignment quality fell just below significance, b = 0.02 (0.01), CI: [−0.002; 0.05]. Vocabulary knowledge negatively predicted the total duration spent on assignment pages which negatively predicted assignment quality which, in turn, positively predicted declarative knowledge. In other words, the marginal indirect path showed that those who had greater vocabulary knowledge spent less time on assignment pages and, consequently, had a higher assignment quality and, ultimately, showed greater declarative knowledge. This serial mediation model predicted 51.7% of variance in declarative knowledge outcomes, whereas a model without assignment quality predicted 48.6% of variance.

4 | DISCUSSION

In the present study, we investigated whether online learning behaviours (navigation activities and writing activities) mediated the relations between learner characteristics (prior knowledge, vocabulary knowledge, working memory, and motivation) and declarative knowledge. In addition, we investigated the extent to which assignment quality could further explain this relation. We expected that a serial mediation model from learner characteristics to declarative knowledge, via online learning behaviour and assignment quality, would explain variance in declarative knowledge outcomes (see Figure 1). The results showed that, in the models that did not include assignment quality, online learning behaviours did not mediate the relations between learner characteristics and declarative knowledge. Once we included assignment quality, however, two serial mediation models showed an indirect effect (one was marginal) from learner characteristics to declarative knowledge, via online learning behaviour and assignment quality. More specifically, prior knowledge predicted declarative knowledge via originality and assignment quality, and vocabulary knowledge predicted declarative knowledge via the time spent on assignment pages and assignment quality.

The first serial mediation model showed that those with greater prior knowledge had lower originality scores, which means they copied more text. Consequently, they achieved a higher assignment quality and finally had greater declarative knowledge. The positive relation between prior knowledge and declarative knowledge is in line with previous research (Ford & Chen, 2000; Kalyuga, 2009). However, at first glance, it may look counterintuitive that copying more text predicted higher assignment quality and declarative knowledge and this contrasts with worries regarding the negative effect of copy-paste activities of students (Kulathuramaiyer & Maurer, 2007). Although copying text may not be justified from an ethical standpoint, its positive relation to assignment quality and declarative knowledge could tentatively be explained by the fact that learners with high prior knowledge are able to select the most relevant passages from the text, whereas low prior knowledge learners are not. Prior knowledge is related to learner's reading comprehension (Verhoeven & Perfetti, 2008) and is negatively associated with experienced cognitive load (Scheiter, Gerjets, Vollmann, & Catrambone, 2009). To achieve a coherent representation of the text, learners need to make inferences about details in the text that are left implicit, which is more difficult when prior knowledge is low (Kirby, Cain, & White, 2012). Copying text may thus be seen as a marker of deeper level understanding: Those who understand the material are able to copy-paste.

The second serial mediation model showed, with a marginal effect, that those with higher vocabulary knowledge spent less time on assignment pages and, consequently, had higher assignment quality and finally also had greater declarative knowledge. The positive relation between vocabulary and declarative knowledge is in line with previous research, as both vocabulary knowledge and reading speed are important aspects of reading comprehension (Hoover, Gough, & Dombey, 1990; Verhoeven & Perfetti, 2008). The negative relation between vocabulary knowledge and time spent on assignment pages may have indicated lower reading ability or reading comprehension. However, vocabulary was related to none of the other page durations, making it unlikely that the effect is only due to the joint relation that vocabulary and reading speed have with reading comprehension. Possibly, children with lower vocabulary have trouble understanding what the assignment is about or what they should do. If they recognize their lack of understanding, they may reread the page, in an attempt to gain this understanding. If they do not reach this understanding, this may result in lower assignment quality and declarative knowledge.

The most important finding of this study is that it is important to take assignment quality into account when explaining how learner characteristics and online learning behaviours predict declarative knowledge. Although online learner behaviours did not mediate the relation between learner characteristics and declarative knowledge in models that did not include assignment quality, they did mediate this relation when assignment quality was included as a second mediator. Earlier studies have already shown the link between cognitive and linguistic factors, as well as prior knowledge with assignment quality (e.g., Segers & Verhoeven, 2009). In fact, it has been noted before that there is not one perfect way to write an assignment. The best path to a good written assignment will depend on the learner's characteristics and skills, as well as on task characteristics (Rijlaarsdam et al., 2005). Moreover, when writing is used as a means of learning, the type of learning activities that are optimal depend on the strategies that learners typically use. For example, students who primarily use a writing strategy that involves a lot of revising benefit from learning activities that focus on revision. Students who use fewer revising strategies benefit more from learning activities that involve planning (Kieft, Rijlaarsdam, & van den Bergh, 2008). As such, the current findings are in line with previous research.

The present results also emphasize the importance of context. Each different assignment will have different task demands that affect learners' choices regarding their online learning activities. As such, the learners' behaviour cannot be seen as independent from the environment it occurs in (see also Richardson, Shockley, Fajen, Riley, & Turvey, 2008). Instead, the learners' characteristics (e.g., vocabulary knowledge), their past experiences (e.g., in the shape of prior knowledge), and the learning environment all interact to produce the learning activities and consequent learning outcomes. From a cognitive load perspective, it has already been noted that the ideal learning environment depends on learner characteristics. For example, the expertise reversal effect shows that the prior knowledge of an individual will affect which environment optimal for learning (Kalyuga et al., 2003). We may add that not only learner characteristics and the learning environment interact, but that this interaction will also affect what the learning process will look like. As such, in order to understand how learners gain knowledge in hypermedia environments, research needs to take into account the context in which learning takes place.

This study has several limitations. A first limitation is that power was limited due to the relatively small sample size and the large number of variables under investigation. Consequently, some caution is needed when interpreting results. In addition, this contributed to our decision to use the process procedure of Hayes (Preacher & Hayes, 2004) for our analyses. We acknowledge that using structural equation modelling could have provided additional information about the added benefit of assignment quality in our mediation models. Our current sample size did not allow for this, however. The sample was also more diverse than the average Dutch population. This may have affected generalizability of the results. Analyses showed, however, that Dutch and non-Dutch participants did not differ in their learning gain or assignment quality. This seems to suggest that the existing relations were similar for both categories of participant, despite the fact that initial levels of some learner characteristics differed. Future studies could endeavour to replicate this study's findings to further increase generalizability of the results. A second limitation is that the navigation activities did not include the writing assignment. As a result, no information could be gathered on switches between reading and writing and on whether other measures of the writing process could affect learning. Future studies should therefore endeavour to incorporate the writing assignment into the environment that records the navigation activities. A third limitation of the study is that the declarative knowledge post-test was identical to our prior knowledge measure. Although this has the advantage that pretest and post-test are completely comparable, have sufficient length, and thus are more reliable, it could have resulted in selective reading of the website by participants.

The current study investigated navigation activities as a measure for online learning behaviour. Because navigation activities are sometimes used to study SRL (Jamieson-Noel & Winne, 2003; Winne, 2010), these results may also have implications for SRL research. The results showed the importance of viewing assignment-related pages in explaining the relation between vocabulary and learning outcomes. Possibly, there is some overlap between viewing assignment pages and the metacognitive activities of orienting and planning. It could therefore be useful to investigate to what extent orienting and planning also mediate the relation between child characteristics and learning. In schools, teachers will benefit from making a direct link between the assignment and the learning goal, because learner characteristics, online learning behaviour, and assignment quality all matter for learning. All these aspects interact in complex ways. In addition, the results show that the richness in the terms used and the coherence of the learner's written work stands in direct relation to declarative knowledge gains. As such, it can be recommended that the learning process is given scaffolding, for example, by modelling how to optimally perform the assignment. In addition, the relation between prior knowledge, copying behaviour, and learning outcomes suggests that helping weaker students to distinguish between main points and side issues may help them to improve their knowledge acquisition on the Internet. For children with low vocabulary knowledge, it is especially relevant to monitor whether they understand the assignment instructions.

Summarizing, the current study found that both online learning behaviour and assignment quality were important in explaining the relations between learner characteristics and declarative knowledge. Adding assignment quality to models that predict declarative knowledge from learner characteristics via online learning behaviour was shown to be useful. As such, taking into account the context in which knowledge acquisition takes place is useful in both research and practice.

ORCID

Cindy Paans http://orcid.org/0000-0001-7586-8777

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